SERMA TECHNOLOGIES

HAMAMASTSU PHOTODIODES
(DPD - S8576)
EVALUATION N° 2
(GLAST Project)
REPORT E02P0638 - JULY, 2002

This analysis was performed for :

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1. INTRODUCTION

1.1 Purpose.

Following the results observed (cracks in epoxy on some photodiodes linked to the low temperature) during the first evaluation (report E01P1435) the CEA sent to SERMA Technologies 8 photodiodes from *HAMAMATSU* used in the GLAST project (DPD - S5876), to perform a new evaluation.
The evaluation plan, described in the next pages, is oriented to a low temperature stress and acoustic microscopy.

The tests performed by SERMA Technologies were oriented to Environmental Stress Tests, and Acoustic Microscopy.

All electrical and optical tests were performed by CEA Saclay.

1.2 Procedures & references.

PLAB009	1.2.1.1.1.1.1.1.1 Traitement d'une analyse, SERMA internal procedure,12/03/2001
ILAB033	Acoustic microscopy analysis, SERMA internal procedure,18/09/200
JEDEC J-STD035	Acoustic microscopy for non hermetic encapsulated electronic components
K03-B70219 RevA	Hamamatsu Delivery Specification of custom Dual PIN photodiode S8576
SED-GLAST-Y5300-129PB	Procédure de mesure des caractéristiques électriques des DPDs, Saclay
SEDI-GLAST-Y5300-182PA	Procédure de mesure des caractéristiques optiques des DPDs, Saclay

2. CONCLUSION

The new evaluation performed shows that the low temperature is a major concern for the epoxy resin, three DPDs, from cell without humidity test, were found with crack after the temperature cycling test.

The defects found are summarized here after:

- After 20 cycles -40°C/30°C
  - delamination at epoxy/die, epoxy/ceramic interfaces and cracks in epoxy (# 97)
  - beginning of delamination at epoxy/ceramic interface between die and separator (# 99).
  - beginning of delamination at epoxy/ceramic interface between die and separator (# 125, 157 and 163).
- After 40 cycles –40°C/30°C
  - delamination at epoxy/die, epoxy/ceramic interfaces and cracks in epoxy (# 95 and 99)
  - delamination at epoxy/ceramic (# 94)
  - beginning of delamination at epoxy/ceramic interface between die and separator (# 125, 157 and 163).
  - On all the parts, voids were detected in the die attach interface, particularly on the center of the part # 97.

The electrical and optical measurements show no evolution of the DPD characteristics apart for the PIN A (smaller die) of the part #97 which gave no signal at the end of the evaluation. It is probably due to a lost of contact between the die and the lead.
With an optical microscope, we saw no degradation at the bounding and wire levels. SERMA will do analysis both on the 3 dead DPDs of Evaluation N°1 (#108,110, 126) and on the one of Evaluation N°2 (#97).

3. EVALUATION PLAN

The evaluation was oriented to a temperature cycling test (-40°C /30°C) to evaluate the epoxy resin at low temperature.

In addition, to be consistent with the gluing process of the DPD on the crystal, a bake-out was done on the DPDs. After bake-out, before starting the temperature cycling test, to avoid water condensation at the epoxy surface the DPDs were put in dry pack.

The 8 components submitted to this evaluation were divided in two cells of 4 components:

- One cell (DPDs # 94, 95, 97, 99) was directly submitted to the temperature cycling test after an initial bake-out.
- One cell (DPDs #101, 125, 157, 163), after an initial bake-out, was submitted to humidity absorption, simulated a bad handling and storage of DPDs. Then they were baking out again before the temperature cycling test.

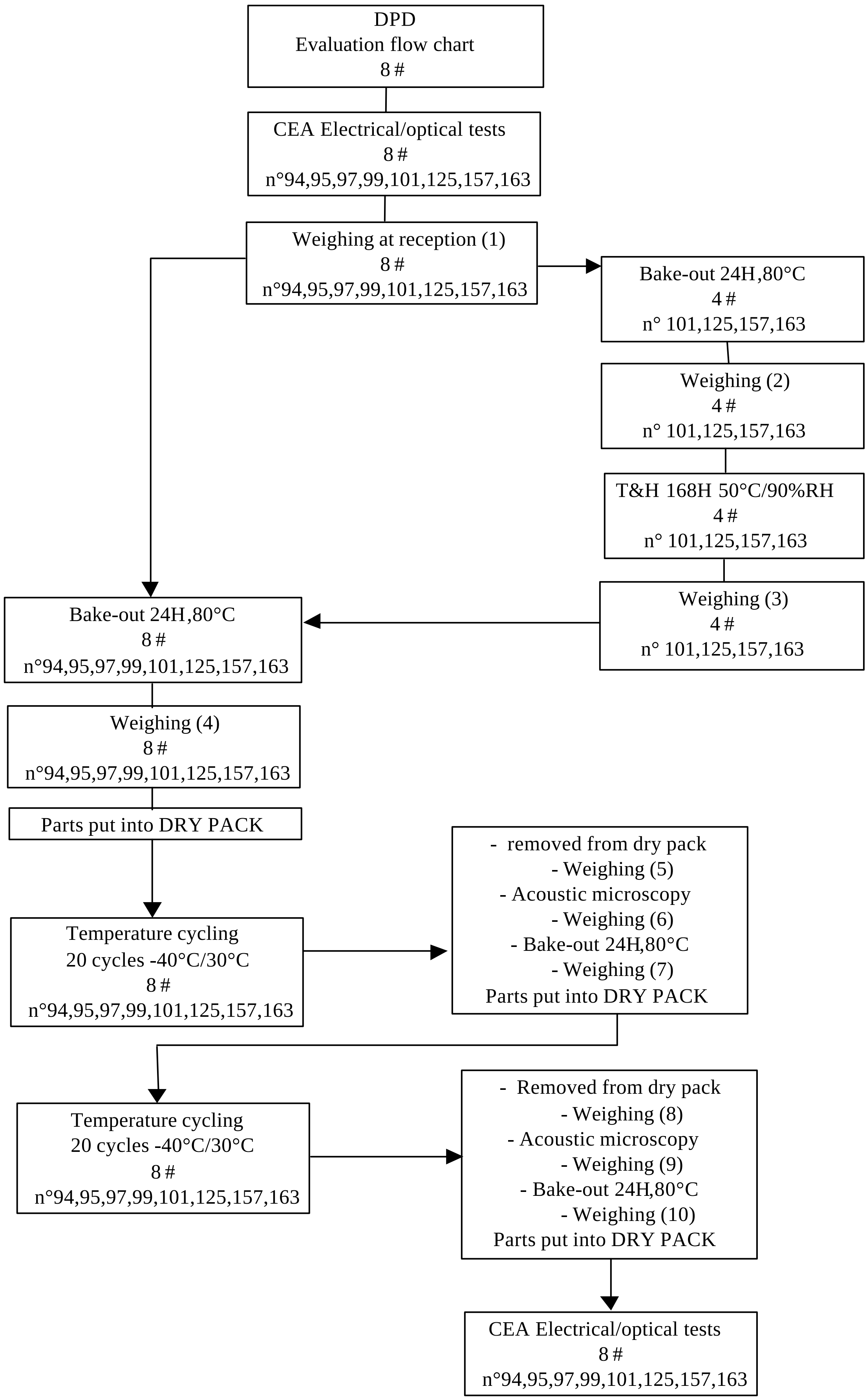
The temperature cycling test was divided in two runs of 20 cycles. At the end of each run an acoustic microscopy was performed on all DPDs.

During the evaluation, the weight of the DPDs was measured all along the tests performed.

The DPDs were electrically (dark current and capacitance) and optically (green and red sensitivity) measured at the beginning and at the end of the evaluation.

The evaluation flow chart is given in next page.

4. EVALUATION FLOW-CHART



5. WEIGHING RESULTS

5.1 Absolute weight results

At each step of the evaluation, the weight (g +/- 10µg) of the DPDs was measured .

					DPD used for T&H 50°C/90%RH					
	94	95	97	99	101	125	157	163	Mean	
reception	1,62083	1,61438	1,59569	1,59776	1,58873	1,59339	1,63382	1,63072	1,60942	w1
initial bake-out					1,58777	1,59240	1,63282	1,62971	1,61068	w2
T&H 168H, 50°C/90%RH					1,58972	1,59439	1,63484	1,63171	1,61267	w3
bake-out before cycles	1,61984	1,61341	1,59474	1,59677	1,58776	1,59240	1,63281	1,62972	1,60843	w4
20 cycles before acoustic	1,61990	1,61346	1,59478	1,59682	1,58783	1,59246	1,63286	1,62979	1,60849	w5
20 cycles after acoustic	1,61992	1,61348	1,59481	1,59683	1,58785	1,59248	1,63287	1,62981	1,60851	w6
bake-out after 20 cycles	1,61985	1,61340	1,59473	1,59676	1,58775	1,59239	1,63282	1,62971	1,60843	w7
40 cycles before acoustic	1,61993	1,61346	1,59482	1,59684	1,58784	1,59248	1,63289	1,62981	1,60851	w8
40 cycles after acoustic	1,61995	1,61349	1,59484	1,59685	1,58785	1,59251	1,63291	1,62983	1,60853	w9
bake-out after 40 cycles	1,61986	1,61339	1,59471	1,59679	1,58777	1,59242	1,63283	1,62974	1,60844	w10

5.2 Weight difference results

The measurements done show the epoxy resin absorb about 2000µg after 168 hours at 50°C/90%RH, and there is no significant weight difference for all bake out performed

					DPD used for T&H 50°C/90%RH						
	94	95	97	99	101	125	157	163	Mean	Rms	
reception	990	970	950	990	970	990	1 010	1 000	984	19	w1-w4
initial bake-out					10	0	10	- 10	2	10	w2-w4
T&H 168H, 50°C/90%RH					1 960	1 990	2 030	1 990	1992	29	w3-w4
bake-out before cycles	0	0	0	0	0	0	0	0	0	0	w4-w4
20 cycles before acoustic	60	50	40	50	70	60	50	70	56	11	w5-w4
20 cycles after acoustic	80	70	70	60	90	80	60	90	75	12	w6-w4
bake-out after 20 cycles	10	-10	-10	-10	-10	-10	10	-10	-5	9	w7-w4
40 cycles before acoustic	90	50	80	70	80	80	80	90	77	13	w8-w4
40 cycles after acoustic	110	80	100	80	90	110	100	110	98	13	w9-w4
bake-out after 40 cycles	20	-20	-30	20	10	20	20	20	7	21	w10-w4

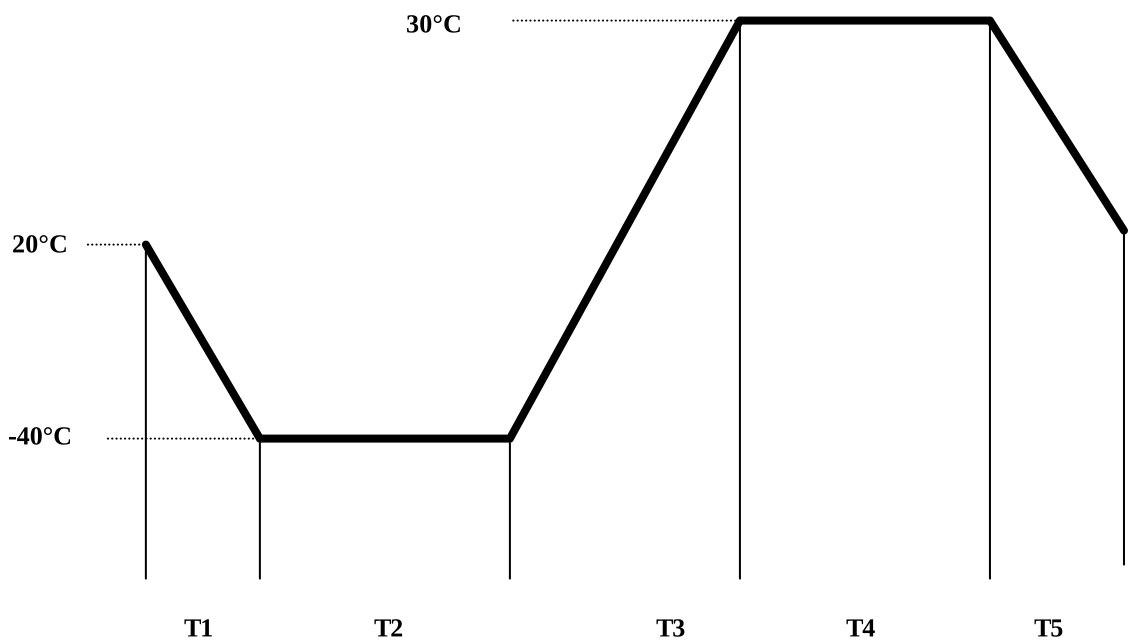
6. THERMAL CYCLES

6.1 Thermal cycles description

To avoid condensation the DPDs were put into a dry pack during thermal cycles stress.

The stress test was performed in two runs of 20 cycles as described hereafter

Condition	Nbr of Cycles	Step duration (minutes)					Slope	Total time
		T1	T2	T3	T4	T5	°C/min	(days)
30°C / -40 °C	20	60	30	70	30	10	1	2,8



6.2 Thermal cycles results

One part (# 97) was found with crack on epoxy resin after the first 20 cycles (see Figure 1).
Two additional parts (# 95, 99) were found with smaller crack on epoxy resin after the 40 cycles (see Figure 2).

These three parts are coming from cell directly submitted to the temperature cycling test after their initial bake-out.

No crack was observed on the 4 parts coming from the cell with humidity absorption.

7. ACOUSTIC MICROSCOPY

7.1 External visual

All parts were optically observed after temperature cycling tests

20 cycles :
A crack in epoxy was detected on part 97 (Figure 1).

40 cycles :
Cracks in epoxy were observed on parts 95 and 99 (Figure 2).

7.2 Acoustic Microscopy

Principle :

The image is formed by the component scanning by an acoustic transducer, the reflected part of the signal at each crossed interface is used to form the image point by point.
If air is found, the reflected signal is inverted which is traduced by a red or a yellow point on the image.

Interpretation :

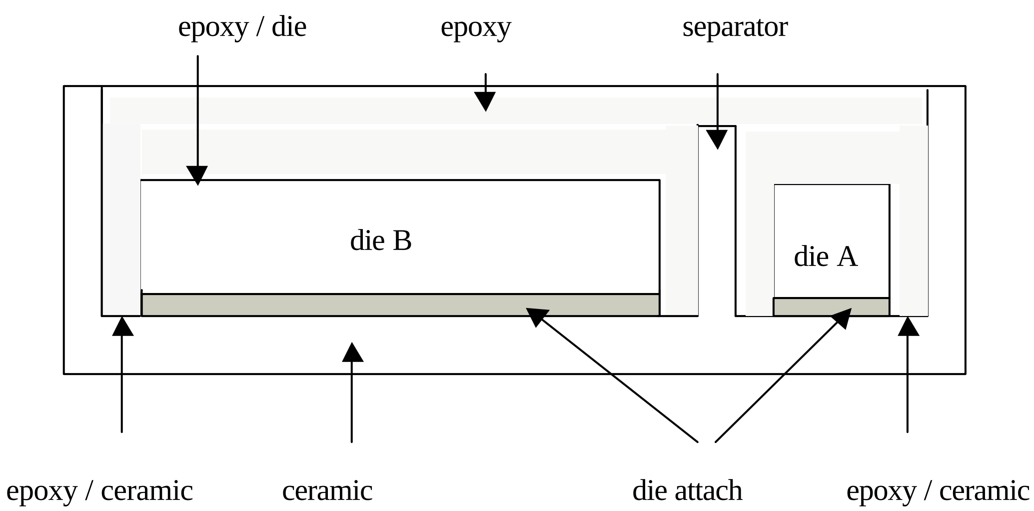
All red or yellow areas are areas which were interpreted as delaminated by the computer algorithm : this is true in the most of case. However, combination of material or structure (fiber, particle…) can induce the same red image without delamination.
This acoustic image in phase inversion must be studied with the acoustic operator comments and not as an absolute information.

Equipment :

SONIX acoustic microscope
Soft SONIX IC LAB/IC PRO Version 4.0 Release 4.01.
Transducer: 75MHz

Acoustic microscopy analysis can detect delaminations at various interfaces :
- Epoxy/die
- Epoxy/ceramic
- Die attach interface

7.3 Interfaces identification



7.4 Acoustic Microscopy results

Top scanning : focus was performed at epoxy/die interface and die-attach interface.
On delamination image (epoxy/die and epoxy/ ceramic observations), delaminated areas are outlined in red or in yellow.
On amplitude image (die-attach observation), areas with a lack of die-attach interface or lack of adhesion are white. In this case, due to component structure, delamination image cannot be taken in account.

Results are given in the following tables :

7.4.1.1 Thermal cycling -40°C/30°C 20 cycles

Top Scanning Figure 3	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy / ceramic
N°94 (628T94)	No	No
N°95 (628T95)	No	No
N°97 (628T97)	Partial + cracks in epoxy	No
N°99 (628T99)	No	Beginning of delamination between die and separator

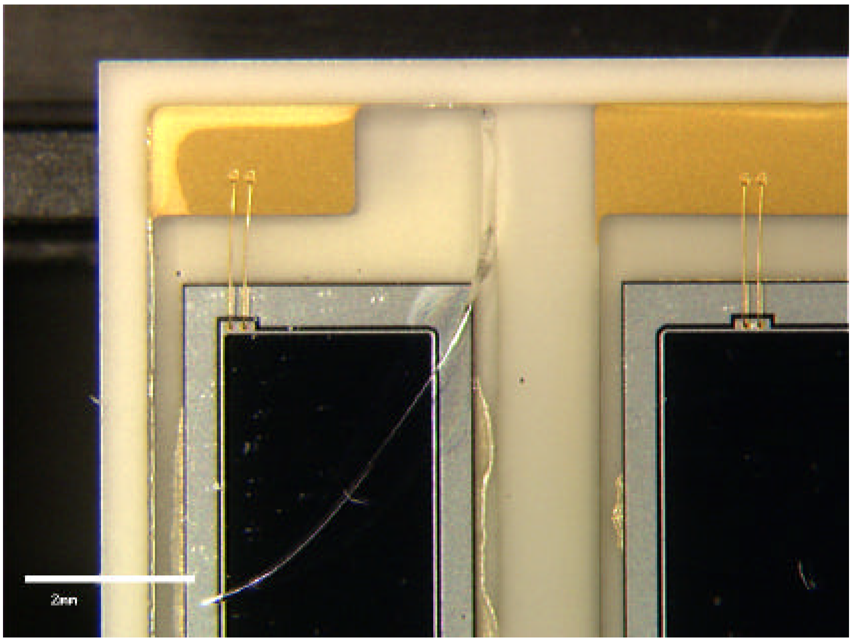
Top Scanning Figure 4	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°101 (628T101)	No	No
N°125 (628T125)	No	Beginning of delamination between die and separator
N°157 (628T157)	No	Beginning of delamination between die and separator
N°163 (628T163)	No	Beginning of delamination between die and separator

7.4.1.2 Thermal cycling –40°C/30°C 40 cycles

Top Scanning Figures 5 and 6	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°94 (628T94S/628D94S)	No	Partial
N°95 (628T95S/628D95S)	Partial + cracks in epoxy	Partial
N°97 (628T97S/628D97S)	Partial + cracks in epoxy: The delaminated area size is minimized by the presence of water in the diode package.	Partial
N°99 (628T99S/628D99S)	Partial + cracks in epoxy	Partial

Top Scanning Figures 7 and 8	DELAMINATION AT INTERFACE	
Part reference (image ref.)	epoxy/die	epoxy/ ceramic
N°101 (628T101S/628D101S)	No	No
N°125 (628T125S/628D125S)	No	Beginning of delamination between die and separator
N°157 (628T157S/628D157S)	No	Beginning of delamination between die and separator
N°163 (628T163S/628D163S)	No	Beginning of delamination between die and separator

On all the parts, voids were observed in the die-attach (white areas on amplitude image).



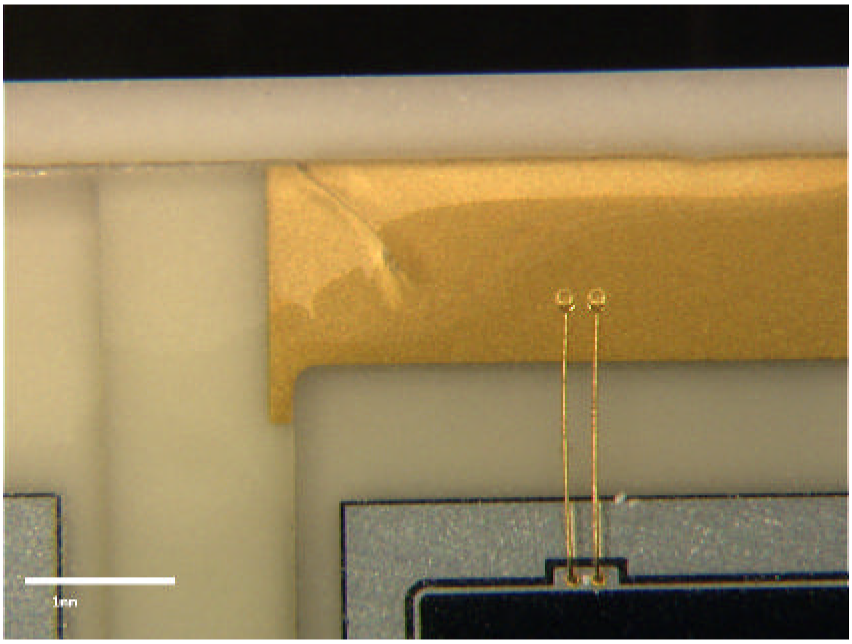


Figure 1. Optical views of cracks in epoxy.
Top : mag ≈ 12X ; bottom : mag ≈ 22X.

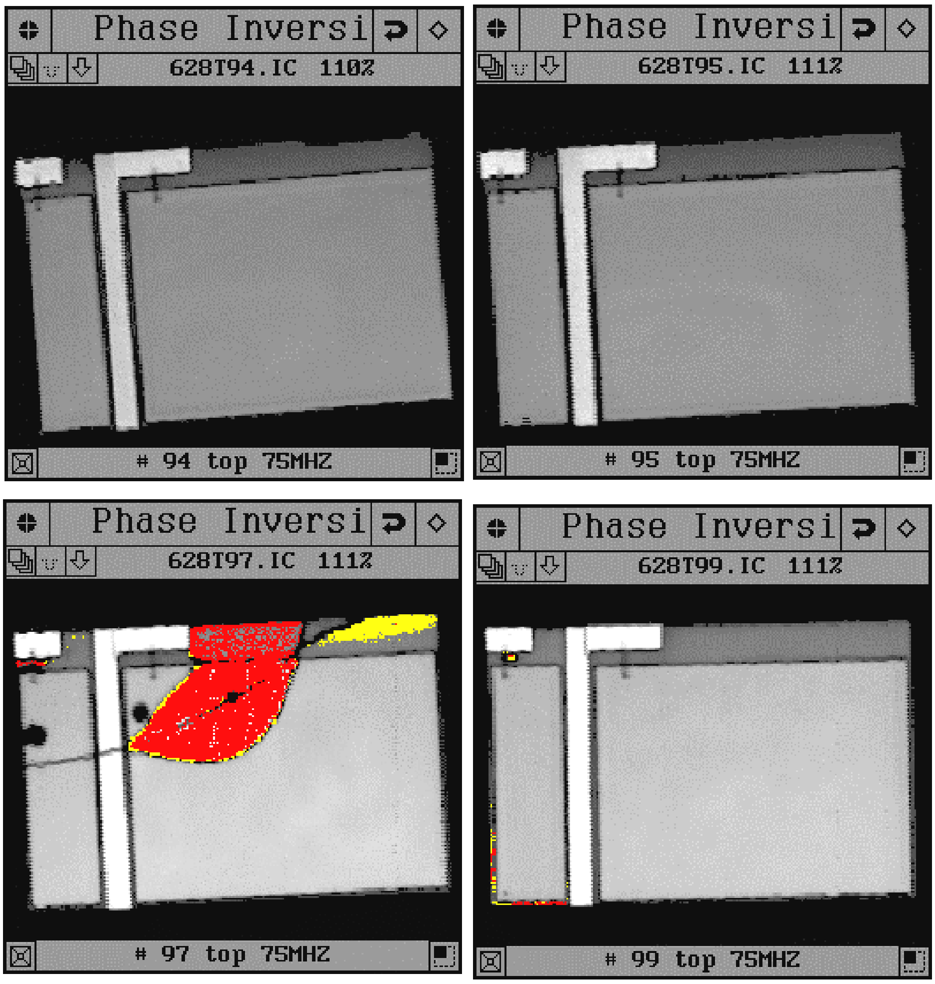


Figure 2. Acoustic microscopy, Parts 94, 95, 97 and 99.
Thermal cycling -40°C / 30°C, 20 cycles.
Delamination images : epoxy / die ; epoxy / ceramic.

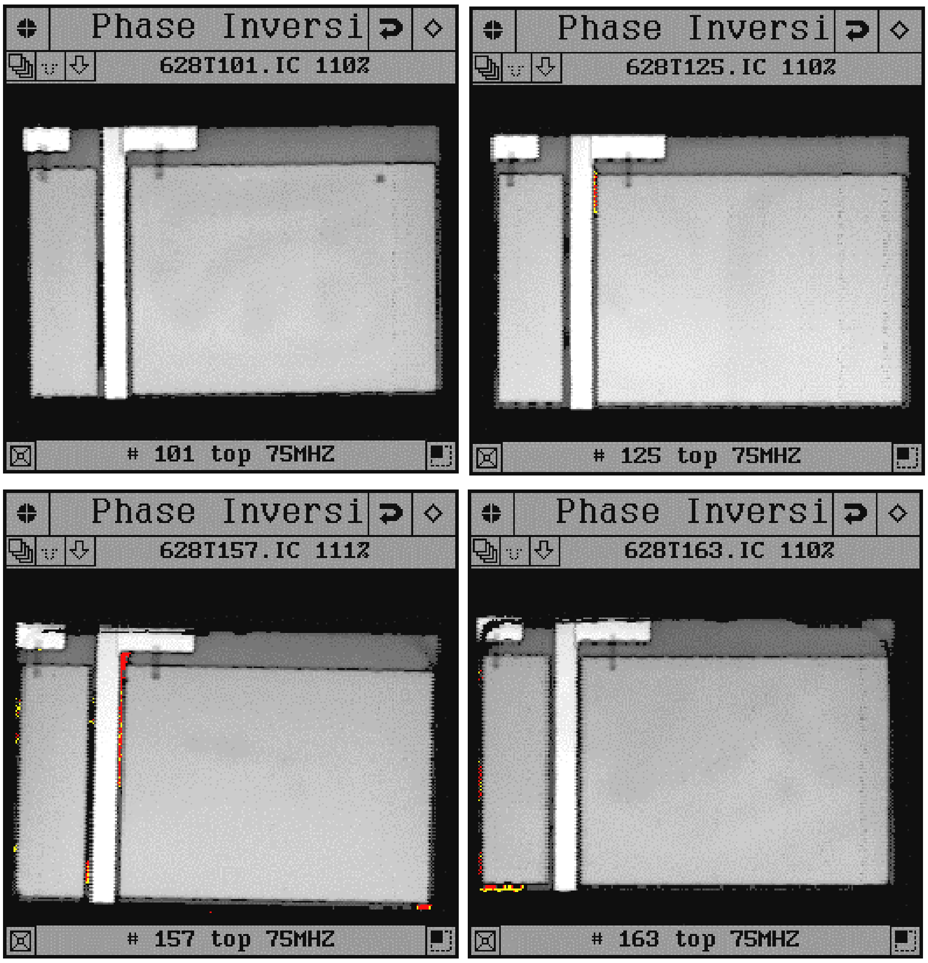


Figure 3. Acoustic microscopy, Parts 101, 125, 157 and 163.
Thermal cycling -40°C / 30°C, 20 cycles.
Delamination images : epoxy / die ; epoxy / ceramic.

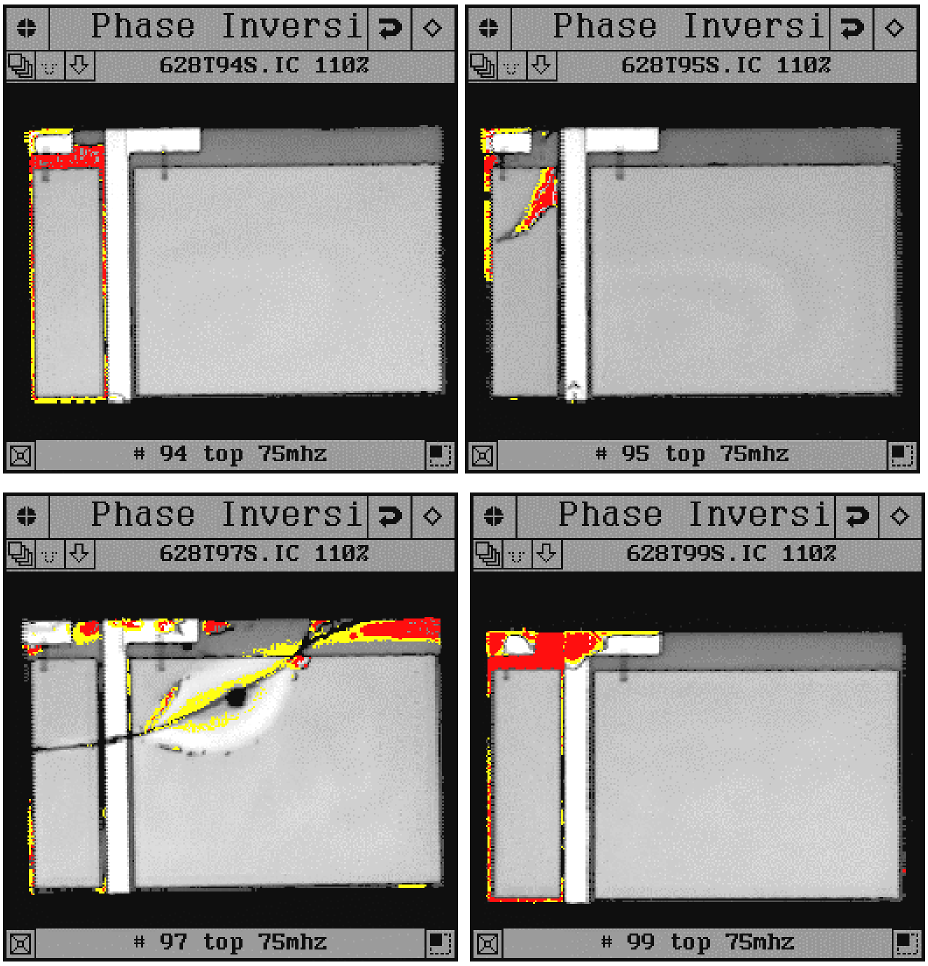


Figure 4. Acoustic microscopy, Parts 94, 95, 97 and 99.
Thermal cycling -40°C / 30°C, 40 cycles.
Delamination images : epoxy / die ; epoxy / ceramic.

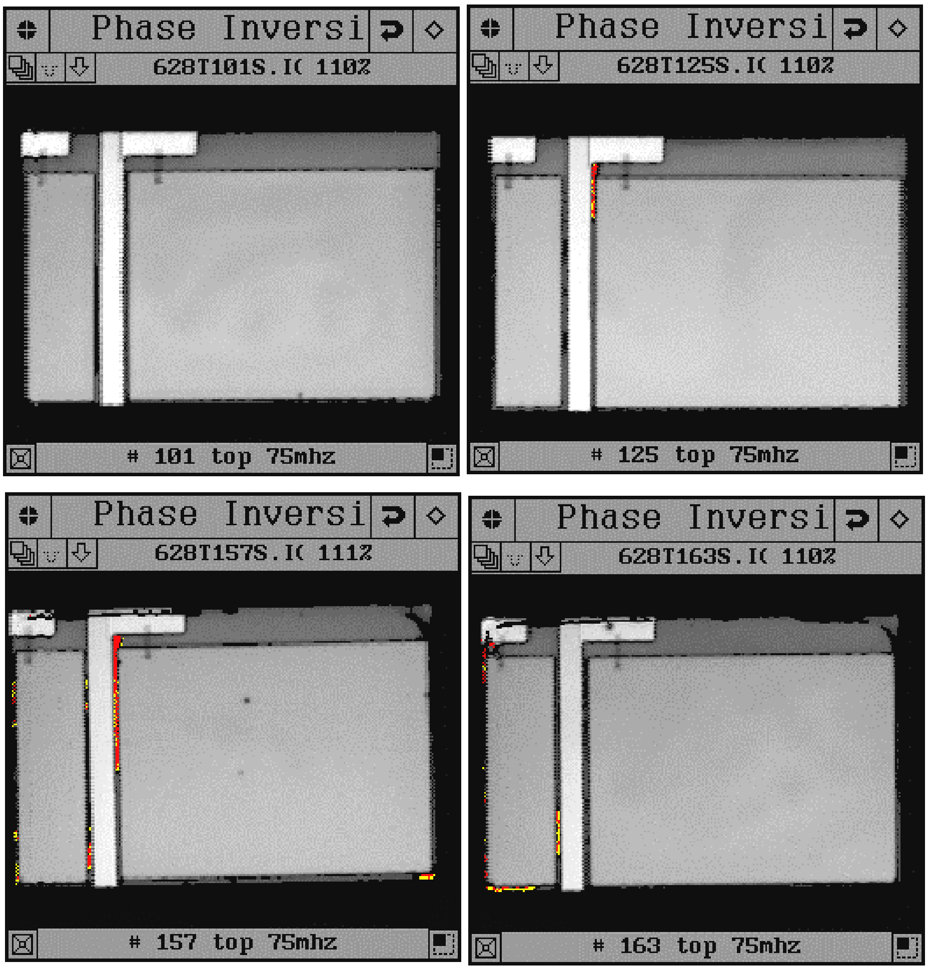


Figure 5. Acoustic microscopy, Parts 101, 125, 157 and 163.
Thermal cycling -40°C / 30°C, 40 cycles.
Delamination images : epoxy / die ; epoxy / ceramic.

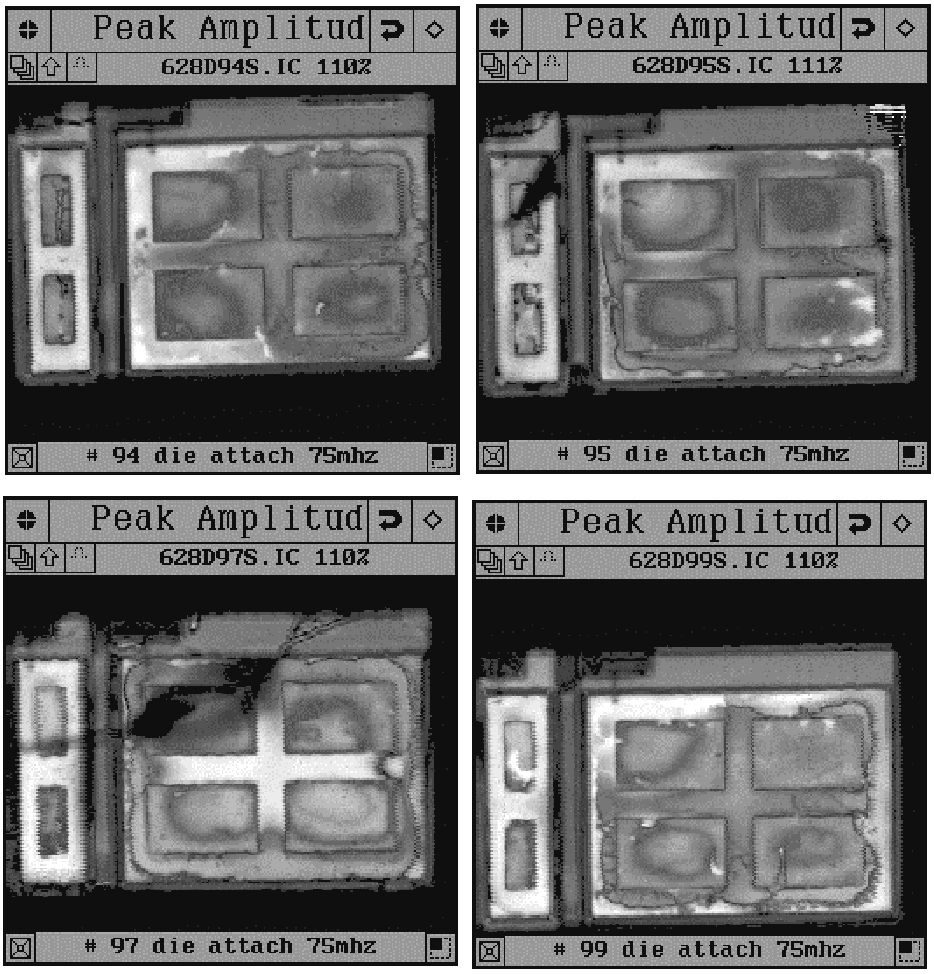


Figure 6. Acoustic microscopy, Parts 94, 95, 97 and 99.
Thermal cycling -40°C / 30°C, 40 cycles.
Amplitude images : die attach interface.

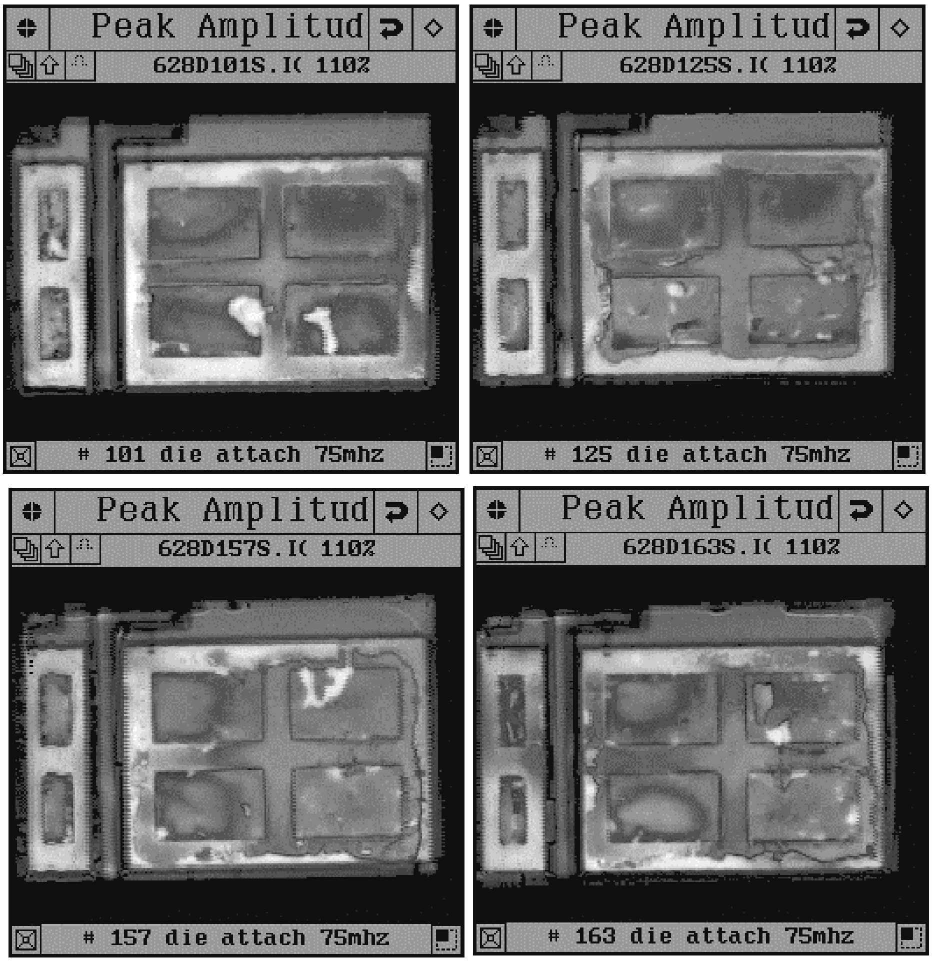


Figure 7. Acoustic microscopy, Parts 101, 125, 157 and 163.
Thermal cycling -40°C / 30°C, 40 cycles.
Amplitude images : die attach interface.

8. ELECTRICAL & OPTICAL MEASUREMENTS

Measurements has been performed at CEA:

- Electrical
- Dark Current of the 2 PIN photodiodes (A and B), the DPD polarized at 70V
- Capacitance of the 2 PIN photodiodes (A and B), the DPD polarized at 70V at 1MHz
- Optical
- Sensitivity of the 2 PIN photodiodes (A and B), the DPD polarized at 70V illuminated at 525nm
- Sensitivity of the 2 PIN photodiodes (A and B), the DPD polarized at 70V illuminated at 660nm

Note as the working temperature of the DPDs is an important parameter essentially for the Dark Current, we have used two DPDs as reference (#100-103) to correct this dependence.

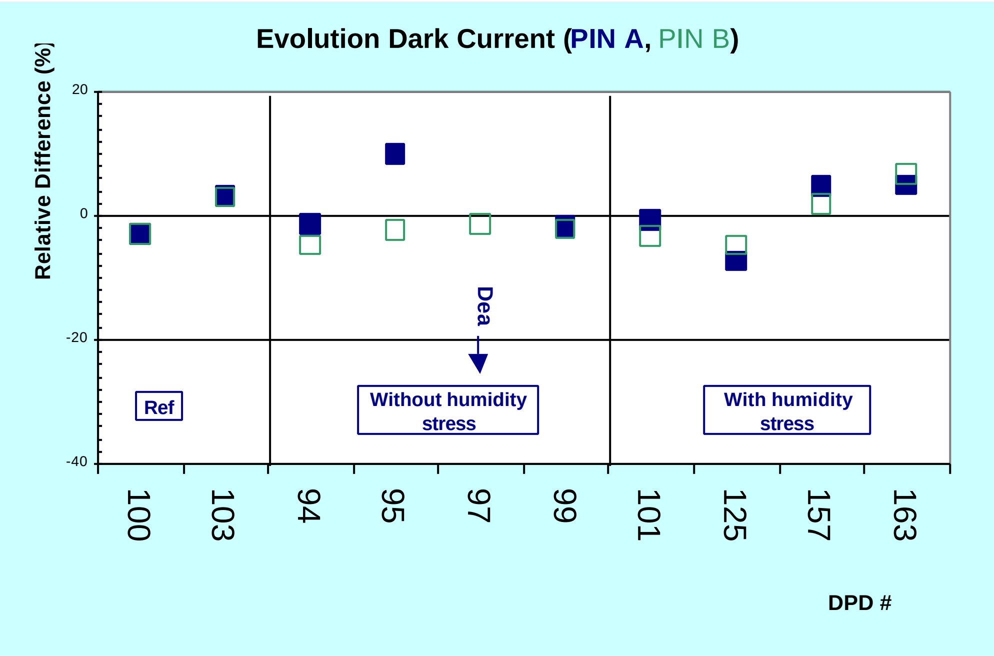
The results are summarized in the following tables and graphs.

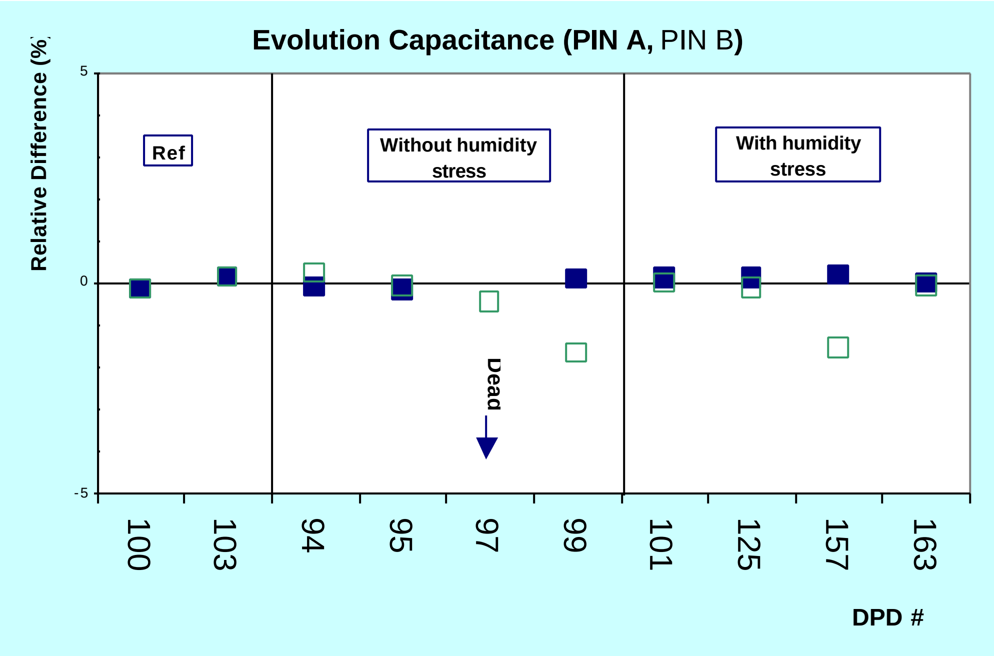
The electrical and optical measurements show no evolution of the DPD characteristics apart for the PIN A (smaller die) of the part #97 which gave no signal at the end of the evaluation.

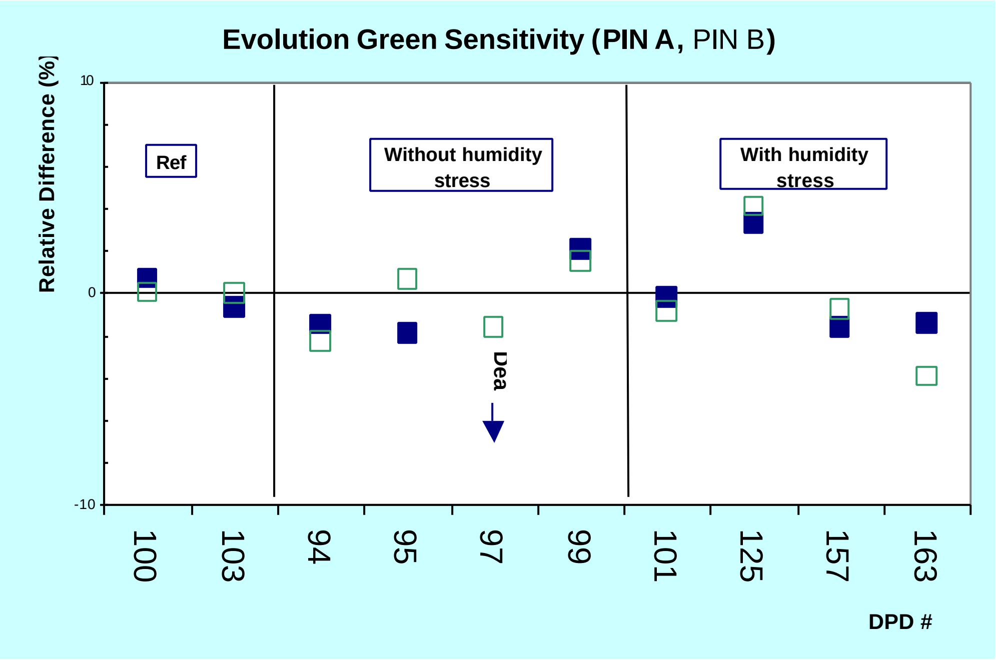
	Measurements before sending at SERMA: To							
DPD#	ID(A) nA	ID(B) nA	Ct(A) pF	Ct(B) pF	S(A) 525nm A.U.	S(A) 660nm A.U.	S(B) 525nm A.U.	S(B) 660nm A.U.
100	1,03	2,64	15,48	63,70	227	854	1270	932
103	1,07	2,77	15,47	63,52	227	843	1263	928
94	1,14	2,69	15,48	63,49	226	871	1292	950
95	1,07	2,54	15,49	63,70	225	847	1258	921
97	1,11	2,68	15,53	63,79	220	846	1273	925
99	1,12	3,00	15,53	63,88	222	844	1284	931
101	1,28	2,75	15,55	63,62	224	851	1292	940
125	1,16	3,69	15,52	63,66	221	819	1268	897
157	1,51	3,81	15,69	63,81	224	845	1284	919
163	1,15	5,35	15,52	63,60	223	835	1294	932

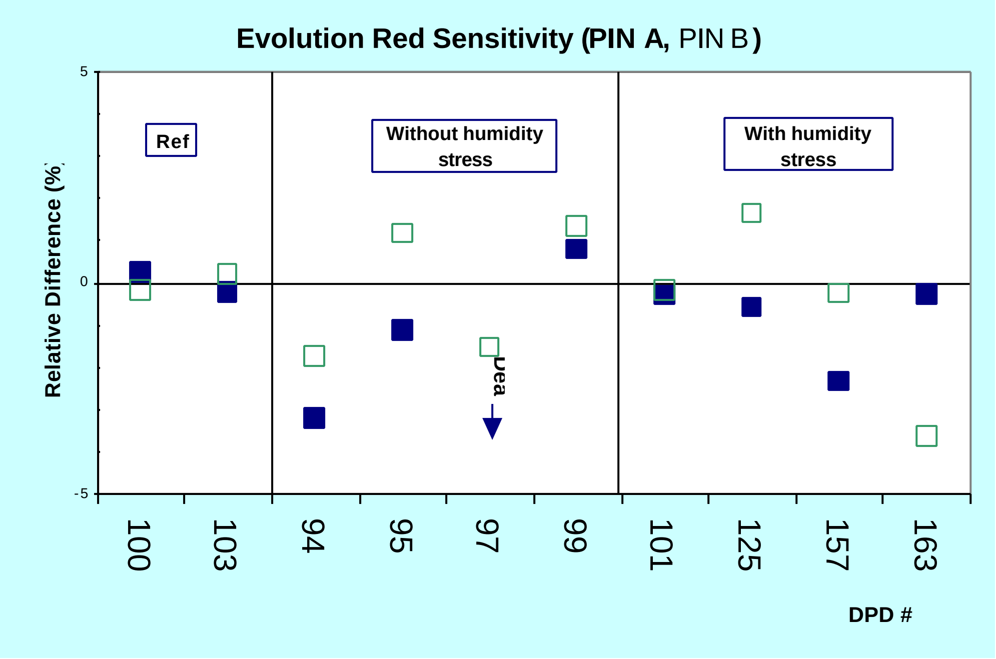
	Measurements after the test at SERMA: absolute values							
DPD#	ID(A) nA	ID(B) nA	Ct(A) pF	Ct(B) pF	S(A) 525nm A.U.	S(A) 660nm A.U.	S(B) 525nm A.U.	S(B) 660nm A.U.
100	1,00	2,56	15,46	63,62	228	856	1270	931
103	1,10	2,85	15,49	63,61	225	841	1263	930
94	1,12	2,56	15,46	63,64	222	842	1262	934
95	1,18	2,48	15,46	63,65	221	837	1266	932
97	0,00	2,64	0,00	63,51	0	0	1252	911
99	1,10	2,93	15,54	62,81	226	850	1304	943
101	1,27	2,66	15,57	63,62	223	848	1281	938
125	1,07	4	15,54	63,58	228	814	1320	912
157	1,58	3,88	15,72	62,82	220	825	1274	917
163	1,20	5,70	15,52	63,55	220	832	1243	898

	Measurements after the test at SERMA: Relative values (after test-To)/To(%)							
DPD#	ID(A)	ID(B)	Ct(A)	Ct(B)	S(A) 525nm	S(A) 660nm	S(B) 525nm	S(B) 660nm
100	-3,12	-3,02	-0,14	-0,13	1	0	0	0
103	3,00	2,88	0,14	0,13	-1	0	0	0
94	-1,52	-4,83	-0,09	0,23	-1	-3	-2	-2
95	9,88	-2,37	-0,17	-0,08	-2	-1	1	1
97	dead	-1,47	dead	-0,44	dead		-2	-2
99	-1,75	-2,32	0,09	-1,67	2	1	2	1
101	-0,94	-3,39	0,12	0,00	0	0	-1	0
125	-7,49	-5	0,11	-0,13	3	-1	4	2
157	4,70	1,83	0,20	-1,54	-2	-2	-1	0
163	4,76	6,51	-0,01	-0,08	-1	0	-4	-4






Evolution Green Sensitivity (PIN A, PIN B)
Relative Difference (%)
10
0
-10
Ref
Without humidity stress
With humidity stress
Dea
100
103
94
95
97
99
101
125
157
163
DPD #


Evolution Red Sensitivity (PIN A, PIN B)
Relative Difference (%)
5
0
-5
Ref
Without humidity stress
With humidity stress
Dea
100
103
94
95
97
99
101
125
157
163
DPD #